Top Quark Forward-Backward Asymmetry And Top Production At The Tevatron

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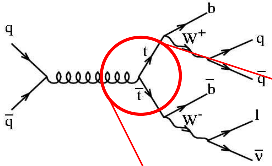
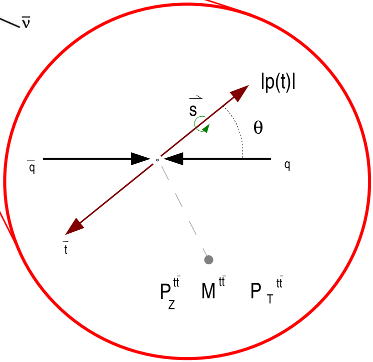
Studying Top Production



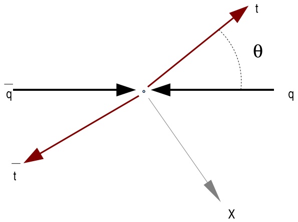
- Mass Of The TTBar System
- Pt Spectrum Of The TTBar System
- Pz Spectrum Of The TTBar System
- Pt Spectrum Of Top
- Production Angle Of Top
- Spin Correlations between Top and TBar

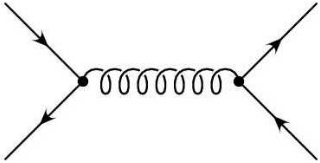


The Forward-Backward Asymmetry Of Top

$$A_{fb} = \frac{N(cos(\Theta){>}0) - N(cos(\Theta){<}0)}{N(cos(\Theta){>}0) - N(cos(\Theta){<}0)}$$

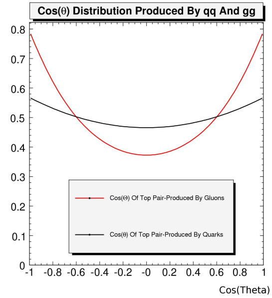
It is a function of the production angle of Top, which is the angle Top emerges from collision with respect to the beamline.





$$\sum |M(q\bar{q} \rightarrow t\bar{t})|^2 = 8g^4(1 + \cos(\theta)^2 + (1 - \beta^2)\sin(\theta)^2)$$

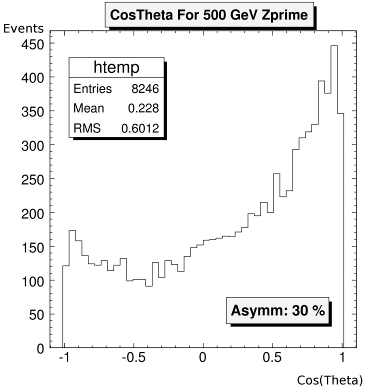
The Production Angle Of Top



$$\sum |M(q\bar{q} \rightarrow t\bar{t})|^2 = 8g^4(1 + \cos(\theta)^2 + (1 - \beta^2)\sin(\theta)^2)$$

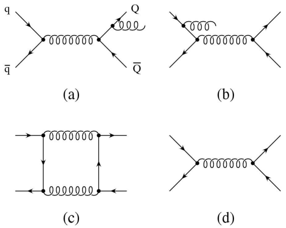
Asymmetry From New Physics

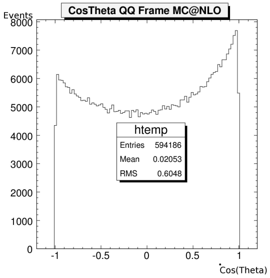
- New physics may show up as an asymmetry such as a massive neutral gauge boson like a Zprime.
- Below is a PYTHIA based Monte Carlo simulated Z' with Z like couplings and a mass of 500 GeV



Asymmetry Due To NLO Effect

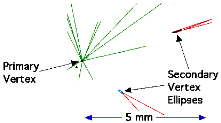
- Good Test Of The Standard Model: Studying A Very Fundamental Distribution
- NLO effect causes an asymmetry due to diagram interference.
  (Kuhn, Rodrigo, Phys Rev. D 59, 054017, 1999)
  (Bowen, Ellis, Rainwater, Arxiv hep-ph/0509267, 2005)
- Asymmetry predicted to be around 5% in $p\bar{p}$ and 8% in $q\bar{q}$ frames

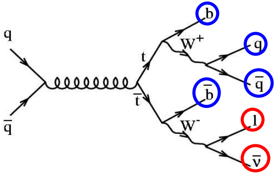


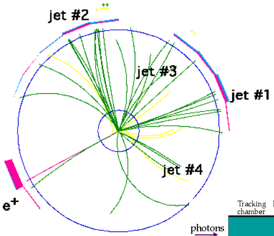


Finding Top Events

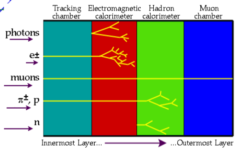
- One Electron Or Muon
  - Isolated
  - Transverse Energy > 20.0 GeV
- 4 Jets Or More
  - 3 w/ Transverse Energy > 15.0 GeV
  - 1 w/ Transverse Energy > 8.0 GeV
- Missing Transverse Energy
  - > 20.0 GeV
- One Jet Tagged As "b quark"
  - A secondary vertex exists in jet.
  - Observed in silicon detector.



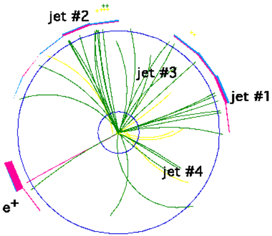




Tracking View

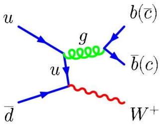


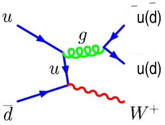
Background

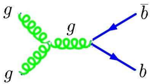


Tracking View

Background	% Of Data
QCD	7.50%
Mistag	9.80%
Wbb	6.50%
Wcc	2.60%
Wc	1.70%
WW/WZ	< 1 %
SingleTop	< 1 %
Total	~ 30 %

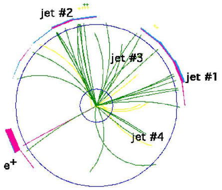




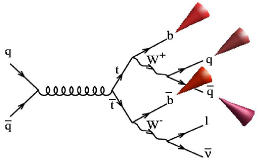


How Do We Get The Top Direction?

We have $\geq$ 4 jets, a lepton, and Missing Transverse Energy. How do we figure out what direction the Top is going? We use an algorithm based on the details of a Top event.



Tracking View



$$\chi^2 = \sum_{i=l,jets} \frac{(p_t^{i,meas} - p_t^{i,fit})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_j^{UE,meas} - p_j^{UE,fit})^2}{\sigma_j^2} +$$

$$\frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{l\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - M_{fit})^2}{\Gamma_t^2} + \frac{(M_{bl\nu} - M_{fit})^2}{\Gamma_t^2}$$

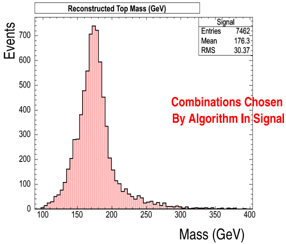
How Do We Get The Top Direction?

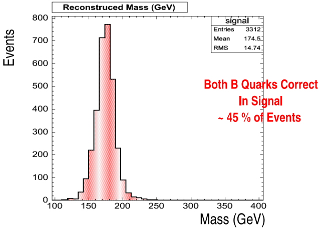
- 12 Different combinations
- Choose one with lowest χ^2
- Terms come from characteristics of Top lepton plus jets events
- Jet and unclustered energies can vary witin error
- Known Top mass may be used as a constraint

$$\chi^2 = \sum_{i=l,jets} \frac{(p_t^{i,meas} - p_t^{i,fit})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_j^{UE,meas} - p_j^{UE,fit})^2}{\sigma_j^2} +$$

$$\frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{lv} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - M_{fit})^2}{\Gamma_t^2} + \frac{(M_{blv} - M_{fit})^2}{\Gamma_t^2}$$

- Reconstructed Top mass MC simulations In MC Simulations For All Combinations And Correct Combinations





How Do We Put Top In The $q\bar{q}$(gg) Frame?

- So we have Top and TBar from fitting
- Recall the reconstruction algorithm solves for the neutrino Pz so we have the complete $t\bar{t}$ 4-vector
- Any additional jets we add into a 4-vector we call X
- Now just add the 4-vectors of Top, TBar, and X and that's what we predict is the $q\bar{q}$ 4-vector
- NOTE: I denote the $q\bar{q}$(gg) frame by QQ

How Well Does It Reconstruct The Production Angle?

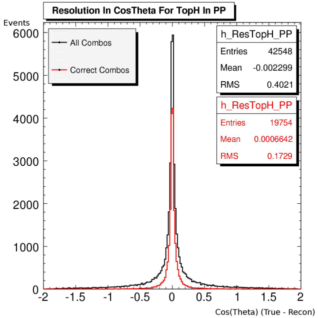


Figure: Reconstructed - True, PP Frame

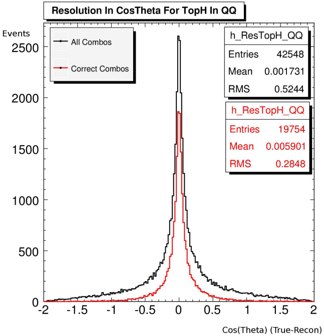
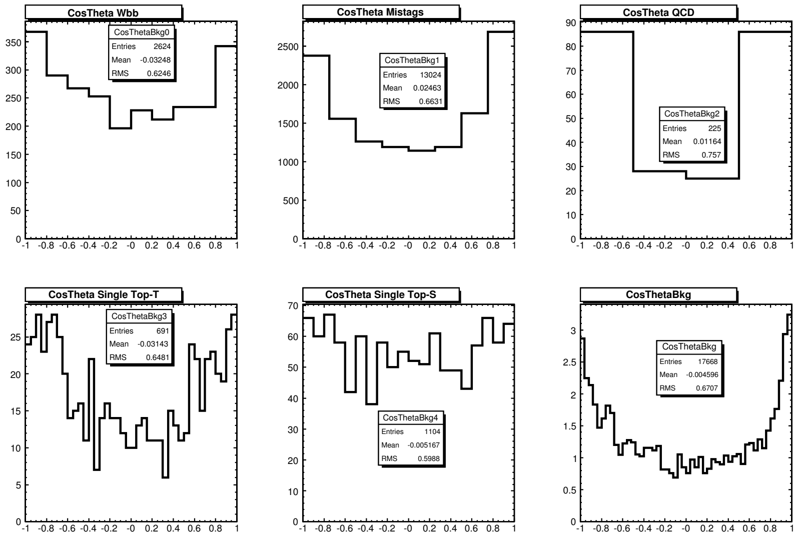


Figure: Reconstructed - True, QQ Frame

Cos(θ) Backgrounds



Smearing By The Reconstruction Algorithm

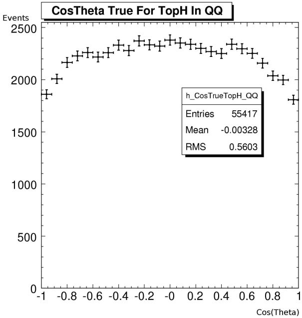


Figure: MC Sim After Cuts

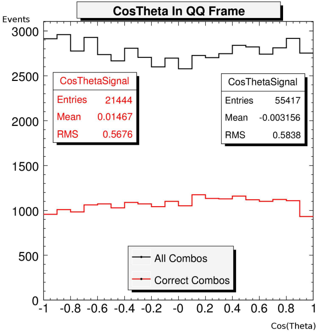
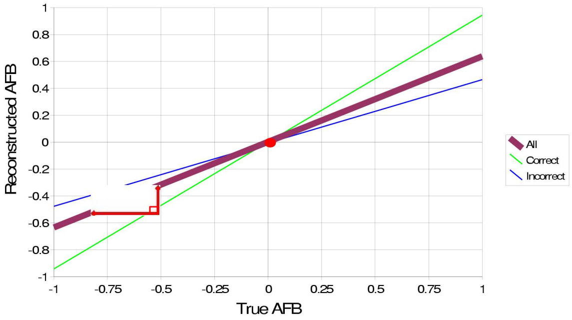


Figure: MC Sim Reconstructed

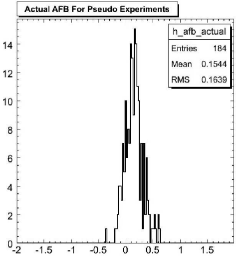
Template Method

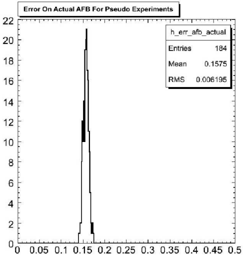
- Several Templates with different A_{fb} are generated
- Afb*Cos(Θ) added to functional form of the production angle
- Approximately linear relationship exists between true Afb and reconstructed Afb
- Slope and offset of fitted line provides a mapping between true and reconstructed Afb

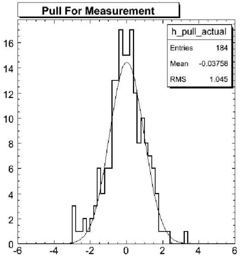


Sensitivity

- Truth Afb: 0.15
- Mean of pseudo experiments: 0.154 +/- 0.012
- Error for measurement at 1 fb^-1: 0.158
- Estimate on error Top/Tbar combined: 0.11
- Pull Mean: -0.038 +/- 0.077
- Pull Width: 1.045 +/- 0.066

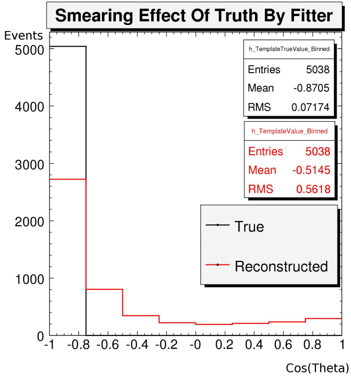






Unsmearing The Effects Of Reconstruction

We Want a way to unsmear the effects of reconstruction to produce a distribution that can be compared to the SM directly.



Monte Carlo Is Used To Determine The Transfer Matrix

$$\begin{bmatrix} \textbf{MC} \\ \textbf{Recon} \\ \text{N X 1} \end{bmatrix} = \begin{bmatrix} \textbf{T} \\ \text{N X N} \end{bmatrix} \begin{bmatrix} \textbf{MC} \\ \textbf{True} \\ \text{N X 1} \end{bmatrix}$$

N = Number Of Bins

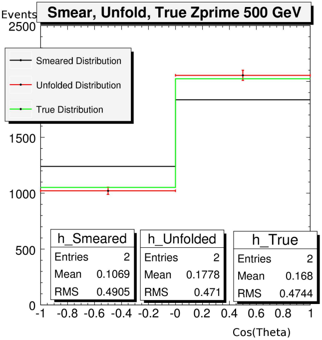
Apply The Transfer Matrix To Data

$$\begin{bmatrix} \textbf{T} \\ \text{N X N} \end{bmatrix}^{-1} \begin{bmatrix} \textbf{Data} \\ \textbf{Recon} \\ \text{N X 1} \end{bmatrix} = \begin{bmatrix} \textbf{Data} \\ \textbf{True} \\ \text{N X 1} \end{bmatrix}$$

The Method Characterizes How The Fitter Smears The Truth
But Makes No Assumptions On What The Truth Might Look Like

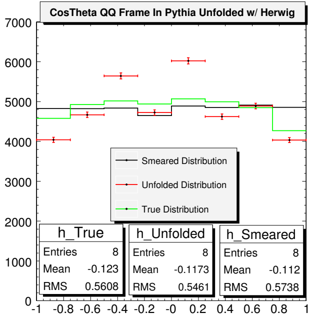
Example: Unsmearing A Z' MC From Pythia Matrix

- Test method with drastically different initial distribution
- Using only matrix inversion
- Using Pythia based Zprime decaying to $t\bar{t}$ with mass $=$ 500GeV
- Put through event selection and then reconstruction
- Unsmeared using matrix formed from $t\bar{t}$ Pythia
- Note just two bins



Many Bin Unfolding In Matrix Inversion

If you ask matrix inversion to unfold too many bins an oscillation effect occurs. Parts of the response matrix are weighted too heavily for the statistics involved.

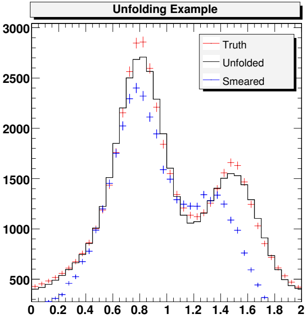


SVD Approach To Data Unfolding

- Based on algorithm by 'Hocker, Kartvelishvili, SVD Approach To Data Unfolding, hep-ph/9509307 (1995)'
- Solves Matrix inversion problem of rapidly oscillating solutions
- This is done by regularization
- Require solutions with only smooth curvature
- Use tools of Singular Value Decomposition to understand what components of solution are important and which should be cut out
- Result of this is a regularization parameter
- Use a regularization parameter to damp out parts that are not important (think Low-Pass filter)
- Unfold based on the regularized matrix

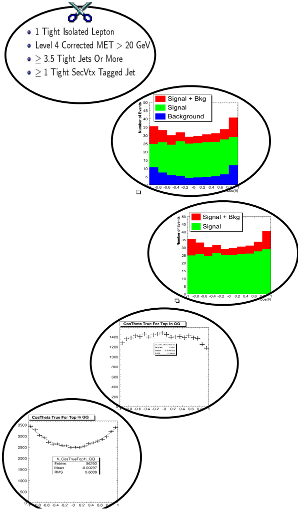
Blobel Example

- Example from 'Blobel, Unfolding Method In High Every Physics Experiments, DESY 84-118 (1984)'
- Response Matrix
  $A(y, y^{true}) = 4(1 - 0.5(1 - y^{true2}))e^{-50(y - y^{true} + 0.05y^{true2})^2}$
- True Distribution
  $X(y^{true}) = \frac{4}{4+(y^{true}-0.4)^2} + \frac{0.4}{0.04+(y^{true}-0.8)^2} + \frac{0.2}{0.04+(y^{true}-1.5)^2}$



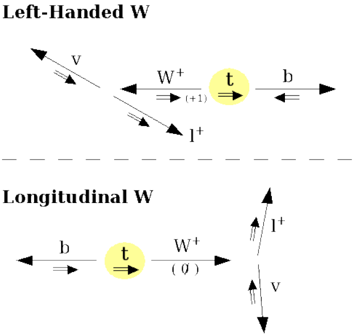
Method

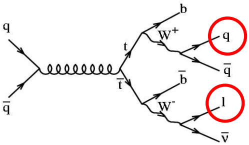
- Select $t\bar{t}$ Candidate Events Out Of Data
- Put Them Through Reconstruction Algorithm
- Subtract Off The Predicted Backgrounds
- Unfold What's Left Over
- Divide By Event Selection Efficiency
- Measure A_{fb}
- Compare To SM
- Graduate



Spin Correlations

- Top passes spin info to decay products.
- Spin correlations translated into angular correlations in decay products.
- Correlations quantified by parameter κ.
- Results in a differential cross-section which is function of κ.
- κ = 0.88 in Standard Model.





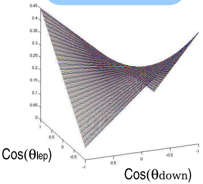
$$\frac{d\sigma}{d\mathrm{Cos}(\theta_{lep})\, d\mathrm{Cos}(\theta_{down})} = \frac{1+\kappa\, \mathrm{Cos}(\theta_{lep})\, \mathrm{Cos}(\theta_{down})}{4}$$

- Schwarz, Miller, Amidei

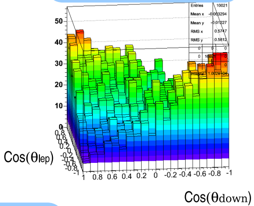
Spin Correlations

$$\frac{d\sigma}{d\mathrm{Cos}(\theta_{lep})\, d\mathrm{Cos}(\theta_{down})} = \frac{1 + \kappa\, \mathrm{Cos}(\theta_{lep})\, \mathrm{Cos}(\theta_{down})}{4}$$

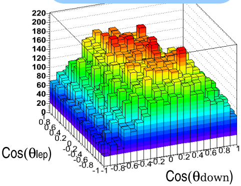
Standard Model



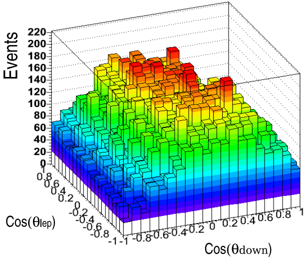
Perfect Reconstruction



Normal Reconstruction



Spin Correlations



$$\frac{d\sigma}{d\mathrm{Cos}(\theta_{lep}^{meas})\, d\mathrm{Cos}(\theta_{down}^{meas})} = \int \frac{1 + \kappa\, \mathrm{Cos}(\theta_{lep}^{true})\, \mathrm{Cos}(\theta_{down}^{true})}{4} \cdot G(\theta_{l,d}^{true}, \theta_{l,d}^{meas}) \cdot \varepsilon(\theta_{l,d}^{true}) \cdot d\theta_{l,d}^{true}$$

- Distortion by reconstruction can be taken into account by smearing and efficiency functions.
- Too complicated to calculate, use Monte Carlo and re-weighting method to perform unbinned likelihood fit.

Spin Correlations

• Sensitivity studies assuming 300 TTBar events:

Lepton And Down Quark
Kappa: 1.07 +/- 0.73

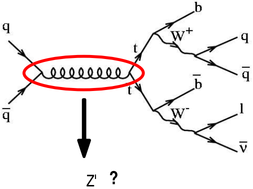
TRUE: 0.93

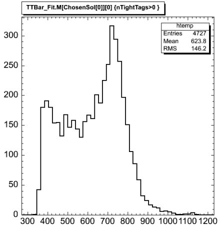
Lepton And Hadronic B
Kappa: -0.33 +/- 0.59

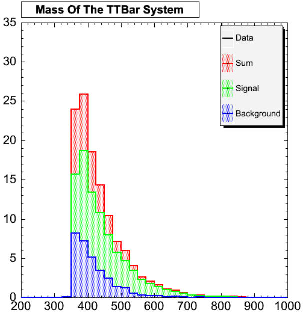
TRUE: -0.39

• Only recorded measure of spin correlations in ttbar is a run I measurement by D0 stating Kappa > -0.25 with 67% confidence level. Measured Kappa = 2.3 with Error +/- 2.5

Resonance In The Mass Of The $t\bar{t}$ System







- Kagan, Miller, Amidei, Schwarz completing analysis that will place limits on possible Zprime in the Mttbar spectrum.

Summary

- Demonstrated a full event reconstruction technique for Top quark events in the lepton plus jets channel
- A template method was presented to demonstrate how the effects of smearing can be circumvented in a measurement of A_{fb}
- An unfolding technique was presented that can reconstruct the entire production angle distribution. It will be used to compare measured kinematic features of Top directly to the Standard Model
- Hopefully demonstrated that a lot of interesting work is being done in the study of Top properties